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LEAKAGE FROM VITRIFIED PIPE USED TO CONVEY WATER UNDER A LOW HEAD¹

BY WILLIAM W. BRUSH

It is frequently of greater value to the water works profession to record the troubles that have been experienced than to describe work which has satisfactorily met all requirements. The Bureau of Water Supply of the Department of Water Supply, Gas and Electricity of the City of New York, has had to repair numerous leaky joints on a vitrified pipe line that was constructed to deliver water under a maximum head of not over 5 pounds per square inch. The following description of this pipe line, the leaks repaired, the tests made of joint material, and the conclusions reached, may be helpful to those who have a similar problem in the future.

General. The Borough of Richmond had an inadequate and unsatisfactory water supply prior to the introduction of the Catskill water, which was made effective in January, 1917. The average daily consumption in the Borough is 12,000,000 gallons. To meet the growth in consumption and to lower the overdraft at existing stations, an additional supply of some 6,000,000 gallons was planned as far back as 1910. A driven well system was to be established along what is known as Southfield Boulevard, a broad public highway running along the southeasterly side of Staten Island. The carrying out of this plan was delayed by various causes, and the new development was not completed sufficiently to be utilized until the spring of 1915. The plant is briefly described as follows:

The central station, known as the Grant City station, has three steam-driven pumps, with a capacity of 12,000,000 gallons, and two electric generators. The supply is derived from five groups of wells, one located at the central station, with two to the northeast and two to the southwest thereof. Electrically driven centrifugal pumps draw the water from the wells and deliver it into collecting lines, through which it flows to a pump well at Grant City station. The four auxiliary stations are operated by power furnished by the

¹Read before the Richmond Convention, May 10, 1917.

central station, the yield of the individual stations varying between 750,000 and 3,000,000 gallons daily. For the two southwesterly stations, a cast iron distribution main has for the time being been used as a collecting main. The two northeasterly stations deliver their supply through an 18-inch vitrified pipe line 7460 feet in length. This pipe line, where it joins the cast iron line from the southwesterly stations, enlarges to a 24-inch vitrified line 557 feet long, which extends to the central pump well. Here the water is drawn by the steam pumps and delivered into the distribution mains under a pressure of about 110 pounds per square inch.

The department proposed to construct the entire collecting line of cast iron pipe, but owing to the short period that would probably elapse between the completion of the development and the introduction of the Catskill water, it was necessary to reduce the construction cost to a minimum. The utilization of an existing distribution main, which was not immediately required to deliver water, satisfactorily solved the problem of a collecting line for the southwesterly section. The substitution of 18-inch vitrified pipe for 16-inch cast iron pipe for the northeasterly section reduced the estimated cost from \$27,000 to \$20,000. At the time the substitution of vitrified pipe for cast iron pipe was recommended, I. M. de Varona, then chief engineer of the Bureau, noted that a risk of excessive leakage was taken, but based upon previous experiments, it was concluded that the joints could be made sufficiently watertight to permit the pipe line to serve its purpose satisfactorily. There was no fear of the pipe itself being of insufficient strength to withstand the pressure, which was estimated at a maximum, under working conditions, of about 5 pounds per square inch.

Vitrified pipe line. The 18-inch pipe was to be the usual sewer pipe $1\frac{1}{4}$ inches thick, with the depth of hub 3 inches, with a maximum variation from these dimensions of 2.5 per cent. The inside diameter of the hub was to exceed the outside diameter of the spigot by not less than 1 inch nor more than $1\frac{1}{2}$ inches. The inside of the hub and the outside of the spigot were to be corrugated. The specification for forming the joints is as follows:

After each length of vitrified pipe has been laid and brought to true line and grade and the spigot fully entered into the hub, a gasket of packing yarn, dipped and saturated in cement grout, which shall have been mixed not more than thirty minutes previously, shall be firmly rammed into the joint with a hardwood calking tool. . . .

The joint material shall be a compound which shall not deteriorate when submerged in fresh or salt water or in solutions slightly alkaline or acid. It shall melt and run freely at temperatures not greater than 250°F. It shall adhere well to the glazed surface of earthenware pipes. . . .

The hubs and spigots shall be thoroughly cleaned before the joint is poured and as dry as reasonably possible. The compound shall be heated in a kettle to a temperature of about 400°F. It shall be frequently stirred. Material which has once cooled shall not be reheated. . . . The compound shall be poured in a full stream so as to fill the entire space before it becomes cool. The gate shall be slightly to one side of the crown of the pipe, and the compound poured so that it will run in one direction only around the joint. . . . The depth of the joint shall be about 2 inches and shall not be less than $1\frac{3}{4}$ inches. . . .

The pipe was to be laid to grade on the bottom of the trench, except where the earth would not properly support it, when either timber or concrete supports were to be furnished. The pipe was laid, as far as possible, with a minimum cover of 3 feet.

This contract was awarded to Joseph Johnson's Sons at an estimated cost of \$19,209.37, which also included the furnishing, delivering and laying of some 1200 feet of cast iron pipe, mainly 20 and 12 inches in diameter, the construction of the pump well, and other miscellaneous work, as well as the vitrified pipe. The price submitted for furnishing, delivering and laying the 18-inch vitrified pipe was \$0.90 per lineal foot; for 24-inch vitrified pipe, \$1.25 per lineal foot; and for earth excavation and backfilling, \$0.50 per cubic yard. These were considered fair prices for this portion of the work. The contractor was ordered to begin work on September 28, 1914, and was allowed seventy-five working days for completion. The need of the additional supply was urgent, and the work was prosecuted from early in October until January 16, the pipe laid each month being as follows: October, 1540 feet; November, 3016 feet; December, 2985 feet; January, 500 feet.

The cold weather interfered with the work, as did also the water in the trench, due to the ground water level being above the pipe invert at some places. The contractor selected for the joint compound an asphaltic mixture known as Filtite A, which was the material previously used in tests made by the Bureau and which had been successfully used in sewer work in Brooklyn. The laboratory report on a sample of the compound was as follows:

Examination shows this material to be a compound of asphaltic base with petroleum residue containing about 50 per cent of mineral matter.

It is apparently unaffected after forty-eight hours immersion in fresh and salt water, and in weak acid and alkaline solutions. Previous experiments upon similar materials indicate that it will not be materially affected.

At 205°F. it is a viscous liquid, flowing somewhat slowly, like cylinder oil.

After two hours exposed to a temperature of 220°F. it loses only 0.11 per cent in weight.

After the contract was completed the following analyses were made:

The following are the results of analyses of three samples of pipe joint compound, received at the laboratory April 20, 1915. The samples were marked as follows:

No. 73. Filtite A. Sample of pipe joint compound used on contract 1356; sent by order of the Chief Engineer.

No. 74. Jointite material used at Grant City, S. I.

No. 75. Jointite material furnished by the Pacific Flush Tank Company, for test at North Portland Avenue Yard, Brooklyn.

No. 72. For comparison) Filtite, made by Pacific Flush Tank Company, taken from barrel on work at Grant City P. S., October 8, 1914, on Contract 1356.

	NUMBER 73	NUMBER 74	NUMBER 75	NUMBER 72
	<i>per cent</i>	<i>per cent</i>	<i>per cent</i>	<i>per cent</i>
Analysis of compound:				
Clay (ash by ignition).....	62.07	61.27	54.42	49.73
Bitumen.....	37.93	38.73	45.58	50.27
Analysis of bitumen:				
Petrolene.....	70.50	70.33	69.02	
Asphaltene.....	29.50	29.67	30.98	
Fixed carbon.....	8.67	7.75	11.61	

The analyses show that the compound is not entirely uniform; the bitumen in sample No. 75 is somewhat harder than the others, as shown by the fixed carbon. There does not seem to be sufficient difference between the samples to account for the failure of the work.

The engineer in charge of the field work reported that the joints were made in accordance with the specifications; that the joints were carefully cleaned after the cement saturated yarn was rammed into place; that the contractors objected to the use of this yarn, as it caused trouble and delay; that the contractors were experienced in the use of the joint compound; and that the work was carefully

performed in accordance with the specifications. The engineer further reported that his examination showed that in spite of the careful cleaning of the joints there was evidence that the cement adhered to the compound and interfered with the adhesion of the asphaltic joint material to the surface of the pipe.

Leakage at joints. When the laying of the pipe had been completed the infiltration of ground water was noticed. The flow was gauged at the central pump well in the latter part of February and early in March, and found to average during a three-day test 43,470 gallons per twenty-four hours. This was equivalent to 163 gallons per joint per twenty-four hours. The seepage clearly indicated that leaks would be found.

On April 7, this line was placed under test, the head being about the working head, and at 22 points in a distance of 1261 feet, water showed on the surface. Here the boulevard is on a fill over a swamp and the foundation for the pipe is consequently somewhat unstable. When the leaky joints were examined the conditions disclosed might be described under these three heads:

First. Where a separation existed between the joint compound and the barrel of the pipe or between the joint compound and the hub. This separation varied from the merest hair-line opening to an amount which would admit the passage of a knife blade.

Second. Where the joint compound had started to blow out, in general more at the bottom of the pipe than at the top, varying from the merest indication of starting to cases where pieces of the compound were ready to fall out.

Third. Where the joint at the bottom was entirely blown out. In some cases the pieces of joint material were thrown out by the laborers in excavating.

On April 14, the contractor had re-run the leaking joints and on April 15, the pipe was again subjected to test by operating both pumps in the most easterly station. Fifteen leaks developed on this test. After a discussion as to the responsibility of the contractor to repair all leaks, under a clause which required a year's guarantee of all the work, he made the repairs, beginning June 4, finding 58 joints to be replaced.

Leaks have continued on this line since then up to the shutting down of the plant in February, the record being as follows:

	1915	1916	1917
January.....		19	4
February.....		26	6
March.....		36	
April.....		10	
May.....		11	
June.....		*	
July.....	11	19	
August.....	4	36	
September.....	4	66	
October.....	3	29	
November.....	8	6	
December.....		24	

* End of maintenance period by contractor.

The contractor made all his repairs by removing the joint material and re-running the joint. The department men tried various schemes, the one mainly used being to drive the joint material into the hub, calk in lead wool, and then place a concrete block around the joint, as shown in figure 1. The repaired joints, in general, did not leak again. Practically no trouble was occasioned by split pipe, only one or two being found in the whole line.

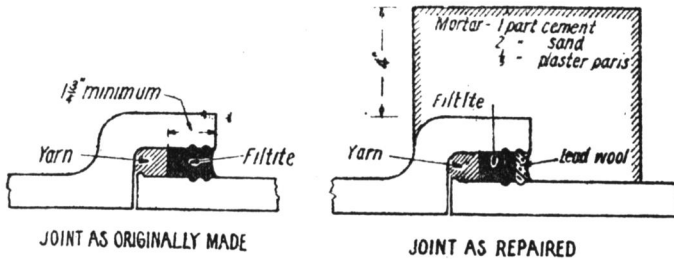


FIG. 1. TYPES OF JOINTS

Experimental tests of joints. In 1912 the Bureau had tested 12-inch vitrified sewer pipe, using the G. K. compound and Jointite, the latter being the predecessor to Filtite, and practically the same material. This test showed the joint would stand 29 pounds per square inch. At the same time joints made of plain yarn, with yarn soaked in cement grout and with lead wool, gave very unsatisfactory results. At an earlier date cement joints poured also leaked freely.

After the leaks were discovered two tests were made, one in the field at Grant City, and one at the Portland Avenue yard in Brooklyn.

The Grant City test, which is illustrated by the photograph, was as follows: On May 19, 1915, work was started, the three pipe joints being calked with grout soaked yarn, after which the joint space was thoroughly cleaned and dried. The joints were then run with the joint compound. On May 22, the joint runners were



FIG. 2. CLOSE OF TEST AT GRANT CITY PUMPING STATION

removed from joints at 9 a.m.; the joints were carefully examined and found to be good.

At 10.30 a.m. the men started filling the test pipes with water, with the air valve open, under a head draft. The pipes were full at 11.05 a.m. and air valve was closed 12.05 p.m.

	<i>feet</i>
12.40 p.m. No leakage, head increased to.....	8
1.10 p.m. No leakage, head increased to.....	9
1.47 p.m. No leakage, head increased to.....	10
2.20 p.m. No leakage, head increased to.....	11
2.55 p.m. No leakage, head increased to.....	12
3.15 p.m. No leakage, test suspended due to rain, and air valve opened.	

The pressure of 12 feet was again put on May 26, and continued without leakage until May 27, when both joints were leaking. The leakage reduced from a maximum rate for each joint of about 24 gallons per twenty-four hours to about 10 gallons for one joint and 2 gallons for the other, the test continuing until June 14, when the pressure was slowly raised to 35 pounds, and held there for thirty-five minutes with a leakage from one joint of 232 gallons per twenty-four hours. The pressure was then raised to 40 pounds, when a pipe split.

Two test lines, each consisting of three lengths of 18-inch standard deep and wide socket vitrified pipes with bulkheads at the ends, were set up at the North Portland Avenue Yard. The arrangements of these test lines is shown in figure 3.

The joints of one of the test lines were poured with material

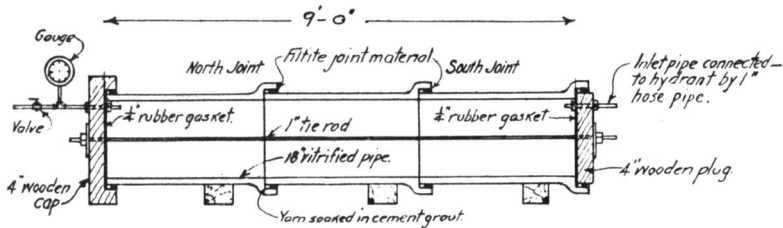


FIG. 3. NORTH PORTLAND AVENUE YARD TEST

received from Joseph Johnson's Sons and the joints of the other line were poured with similar material furnished by the Pacific Flush Tank Company.

The joints were made in accordance with the specifications, a jute gasket dipped in cement grout being used at the back of the joint. The material received from the Pacific Flush Tank Company was first poured. Before pouring, the cement remaining on the surface of the southerly of the two joints in this line was brushed off the pipe so as to leave the pipe clean. The cement was allowed to remain on the surface of the pipe and spigot of the north joint. It was attempted, as specified for the Southfield Boulevard contract, to pour the material through a gate located a little to one side of the top of the pipe, allowing the joint material to flow down and around the pipe and up on the other side. On the joints where the Pacific Flush Tank Company's material was used, this was not

accomplished, the material flowing both ways from the top of the pipe. On the north joint, the clay gasket used to confine the joint material broke through several times during pouring and time necessarily elapsed between successive pourings while the clay was being repaired. The south joint was provided with a rubber hose gasket and no difficulty from breaking out of the material was encountered.

On the line in which the contractor's joint material was used, hose was used as a gasket and the joints were poured, as specified, the material flowing from one side only.

On April 21, these joints were tested under water pressure. At 9 o'clock both pipes were filled to the top with water, and the bulkheads allowed to swell so as to become tighter. The pipe containing the Flush Tank Company's material was tested first, beginning at about 9.40. First water was allowed to flow rapidly into the pipe, the outlet being wide open. Probably a small amount of pressure was developed, although none showed on the gauge. The north and south joints showed slight leakage near the top, but leaks in both cases appeared to be due to shrinkage of the materials.

At 9.50 a pressure of 5 pounds per square inch was applied. The leakage increased somewhat and a small new leak developed in the north joint. At this pressure the south joint leaked at the rate of about 110 gallons per twenty-four hours and the north joint about 540 gallons.

At 10 o'clock, a pressure of 10 pounds per square inch was applied. A new leak developed in the north joint, which is the one in which there was difficulty during pouring. The north joint leaked about 2900 gallons per twenty-four hours; the south joint about 180 gallons.

At 10.06, a pressure of 15 pounds was applied. There were then four decided leaks in the north joint and the leakage was about 4300 gallons per twenty-four hours. No new leaks developed in the south joint and the leakage was not measured.

At 10.11, a pressure of 20 pounds was applied; a new leak developed in the south joint. It was found at 10.14, on account of leakage that it was impossible to hold the pressure at 20 pounds and it dropped to 19 pounds. At that time there was a leakage of about 720 gallons per twenty-four hours from the south joint.

The pressure was taken off at 10.15. The north joint was calked with a wooden calking tool on both sides of the pipe just above the horizontal axis where leaks had developed. On the east side, the joint was found to be hollow, due probably to trouble in pouring.

A pressure of 5 pounds was put on the pipe line again and the leaks were practically the same as before calking.

An attempt was then made to calk the north joint with 5 pounds pressure on the pipe; no improvement in watertightness was apparent. As far as could be observed, calking resulted in failure, since it broke the bond of the material with the pipe and failed to compress the material so as to make it tight against the socket and spigot.

None of the joints in this line showed any signs of movement under 20 pounds pressure.

The line in which the contractor's joint material was used was then put under test at about 10.20. The north joint had been leaking slightly at the bottom since 9 o'clock, when the water was first put into the pipe and before any pressure was put upon it.

At 10.27, the water was passed rapidly through the pipe and both joints showed some very slight leaks.

At 10.30, 5 pounds pressure was applied to the line. The north joint leaked about 48 gallons per twenty-four hours and five minutes later the leakage had increased to about 180 gallons per twenty-four hours. In the south joint there was very little change from the condition under no pressure and the leakage was about 135 gallons per twenty-four hours.

At 10.39, the pressure was increased to 10 pounds. The leakage in the north joint increased at the bottom and side, but no new leaks formed. In the north joint, the leakage was about 270 gallons per twenty-four hours. In the south joint there was no change in the number of leaks, the leakage increasing to about 270 gallons per twenty-four hours.

At 10.45 o'clock the pressure was increased to 15 pounds. No new leaks developed, but the leakage increased in the north joint to about 360 gallons per twenty-four hours, and in the south joint to about 630 gallons.

At 10.50, the pressure was increased to 20 pounds, and at 10.52, while an attempt was being made to measure the leakage, the south joint moved out at the bottom so that no further tests on this line were possible.

The pipe in which the contractor's joint material was used was then broken and the joints removed for examination. It was found that the south joint which failed was deficient in depth at the bottom. The yarn gasket had apparently not been driven back into

the socket sufficiently to permit the full depth of the joint to be poured. The remaining joint appeared to be satisfactory.

The north joint in the line in which the Flush Tank Company's material was used, was then cut out with a cold chisel. This joint was, of course, known to be defective on account of trouble during pouring. It was found that hollow spaces existed in the joint material. There seems, however, to have been no lack of adhesion to the joint, except where the joint had been calked so that the joint material was broken.

Conclusions. The experimental work and the field results showed that the vitrified pipe would safely stand low pressures, say under 25 pounds per square inch, that none of the joint compounds were successful in preventing leakage, but that fairly satisfactory results could be obtained by thoroughly cleaning the joints before running the joints. The use of cement soaked yarn appeared to be detrimental in its effect on watertightness of the poured joint.

The Bureau has been experimenting with calked cement joints for cast iron pipe, following the instructions given by Clark H. Shaw in his paper presented on April 18, 1917, before the American Society of Civil Engineers. These joints have been highly successful under test pressures up to 300 pounds per square inch. There seems to be no good reason why a calked cement joint in a vitrified pipe would not be watertight up to the pressure the pipe would safely stand if care is exercised to calk only to an amount that the hubs will stand without cracking. Experiments along this line are to be undertaken by the Bureau in the near future.